ATTACHMENT I
INDEX TO THE ADMINISTRATIVE RECORD

1. Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs, Radium CAS#7440-14-4. ATSDR. July 1999a.

2. Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs, Radon CAS#14859-67-7. ATSDR. September 1999b.

3. Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs, Ionizing Radiation. ATSDR. September 1999c.

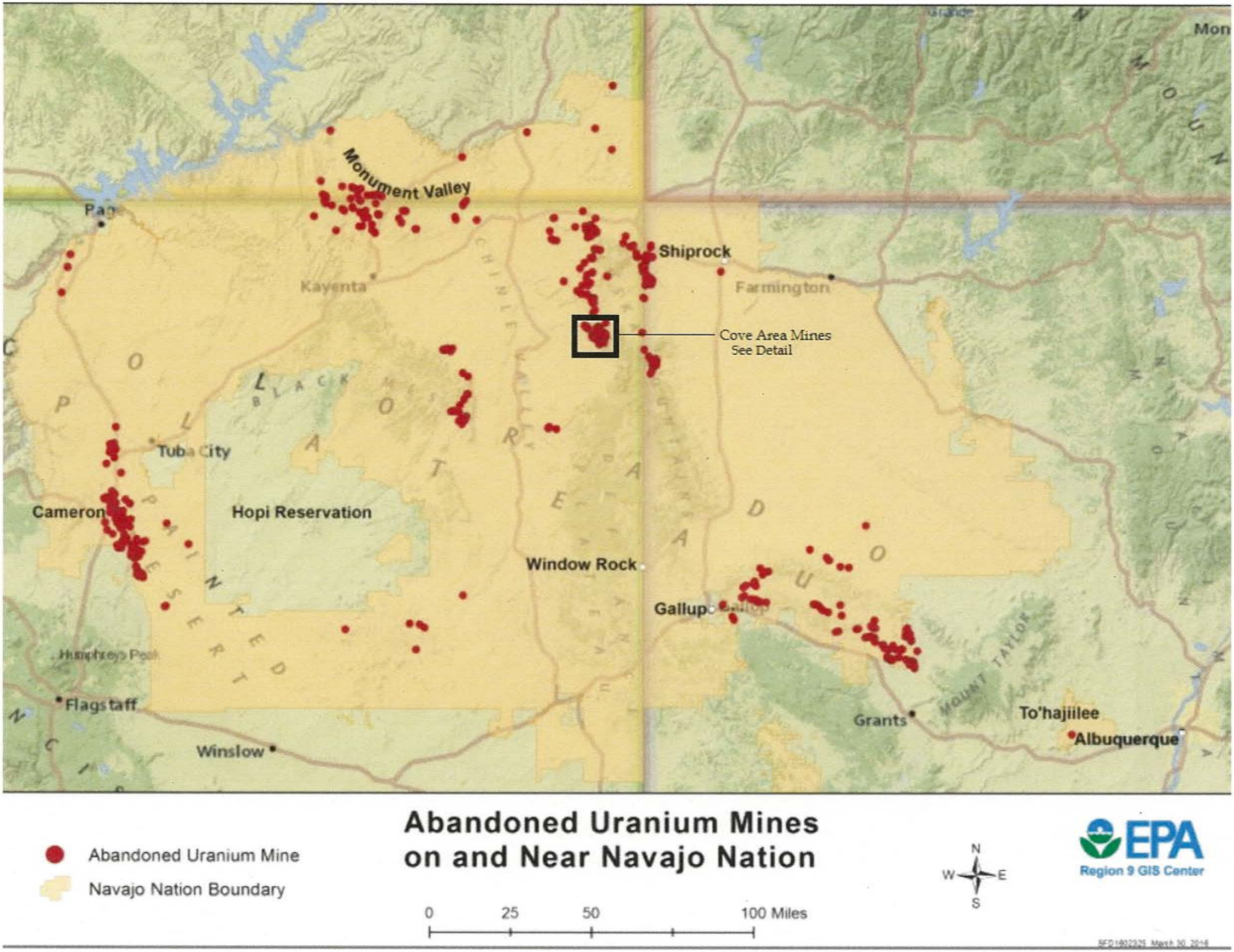
4. Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs, Uranium CAS#7440-61-1. ATSDR. September 1999d.

5. Tronox Mesa V Mine Radon Sampling Project, EPA Office of Radiation & Indoor Air, National Center for Radiation Field Operations, August 7, 2017.

6. Mine Category Assessment Protocol (MCAP) Summary Report Navajo Nation, Apache County, Arizona, Weston, December 9, 2016.

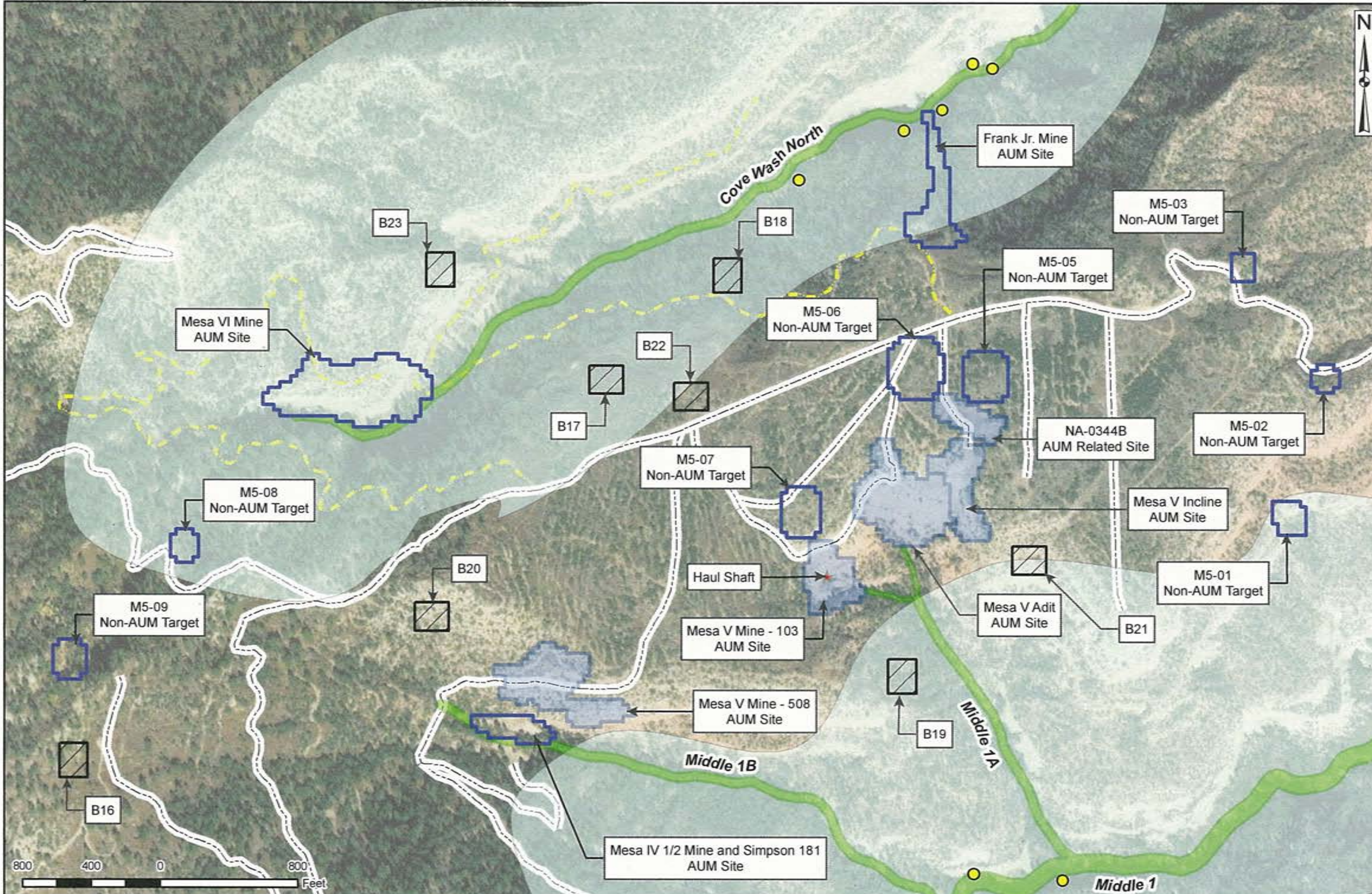
7. Site Location Map – Tronox Mesa V Mine Site

ATTACHMENT II
SITE LOCATION MAP – TRONOX MESA V MINE SITE



Abandoned Uranium Mines on and Near Navajo Nation

Coordinate System: NAD 1983 StatePlane Arizona East FIPS 0201 FeetTransverse Mercator



MSO Observation site - 2018
Protected Activity Center (2018)
Project Area Drill Location
Survey Area - No Drilling
Drainage Survey Area

Background Sample Location

Access Route - Foot
Access Route - Vehicular

Notes:
1) Boring frequency - 10 borings per acre to 20 feet bgs.
2) Boring rate - 5 borings per 8 hour day.
3) All drainages will be sampled using a hand auger to a maximum depth of 5 feet bgs.

Prepared for:

Prepared By:
TETRA TECH
1999 Harrison Street, Suite 500
Oakland, CA 94612

MESA V HAUL SAFT LOCATION FIGURE
COVE CHAPTER

Task Order No.: TO 001	Contract No.: EP-S9-17-03	Figure No.:
Location: COVE CHAPTER NAVAJO NATION	Date: 8/7/2018	

T:\LOCAL OPERATIONS\FORT COLLINS\RADIATION\RAES 2018\FINAL GIS\MXD\TO1\FIELD_PRODUCTS\DRILLING\GROUP_F_DRILLING.MXD 08/07/18

ATTACHMENT III
TRONOX MESA V RADON REPORT

Mesa V Mine Radon Sampling Project

08/07/2017
DCN: REP-Mesa V
Revision: 00

Prepared by:
US Environmental Protection Agency
Office of Radiation and Indoor Air
National Center for Radiation Field Operations
4220 S. Maryland Parkway, Building C
Las Vegas, NV 89119

Prepared for:

US Environmental Protection Agency, Region 9
Superfund Division
Tribal Lands Clean-up Section
75 Hawthorne Street
San Francisco, CA 94105

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1 INTRODUCTION

Portions of the Navajo Nation are located on geologic formations rich in radioactive uranium ores. Beginning in the 1940s, widespread mining and milling of uranium ore on Navajo Nation tribal lands for national defense and energy purposes led to a legacy of abandoned uranium mine (AUM) sites. During the summer and fall of 2015, EPA Region 9 and EPA's START contractors completed the Mine Category Assessment Protocol (MCAP) for the prioritization of Removal Site Evaluations within the Navajo Nation in Apache County Arizona. One location of particular concern is located in the Cove Mesa, AZ area and is identified as "Mesa V Mine", which is the highest scoring site in the MCAP. See Figures 1 and 2 below for maps of the adit location.

The Mesa V Mine site consists of an open mine adit that is accessible by the public and possibly livestock (cattle) as well. EPA Region 9 and the Navajo Nation are concerned that unrestricted access to the site may be a potential public/human exposure pathway to radon gas emitted from exposed uranium ore or waste.

During the week of June 18-23, 2017, National Center for Radiation Field Operations (NCRFO), on behalf of EPA Region 9, monitored the ambient levels of radon gas within the Mesa V Mine adit. The following sections present the investigation methods and results.

Measurement data collected by NCRFO and presented in this report is intended to be used by U.S. EPA Region 9 and the Navajo Nation to evaluate/assess doses/risks to persons that may enter the adit.

Figure 2. Map of AUMs on the Navajo

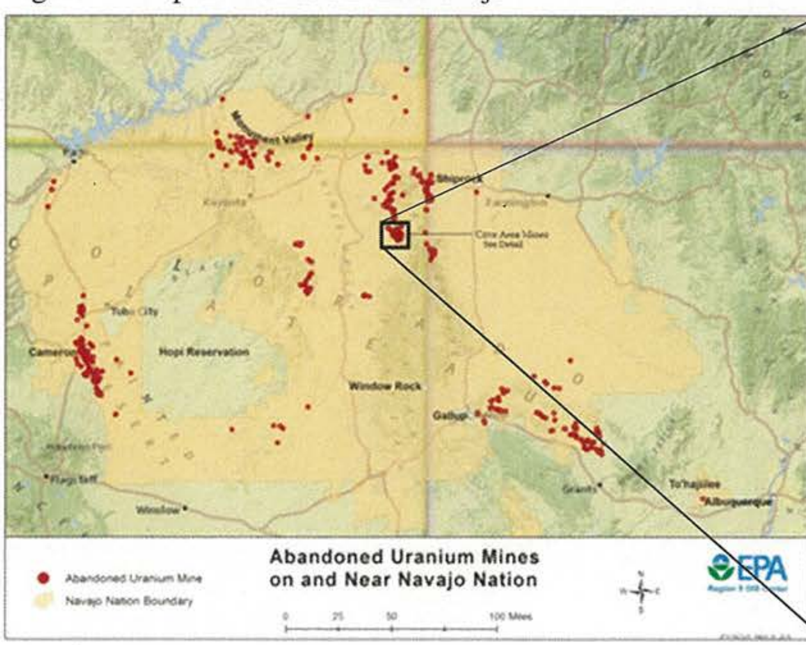
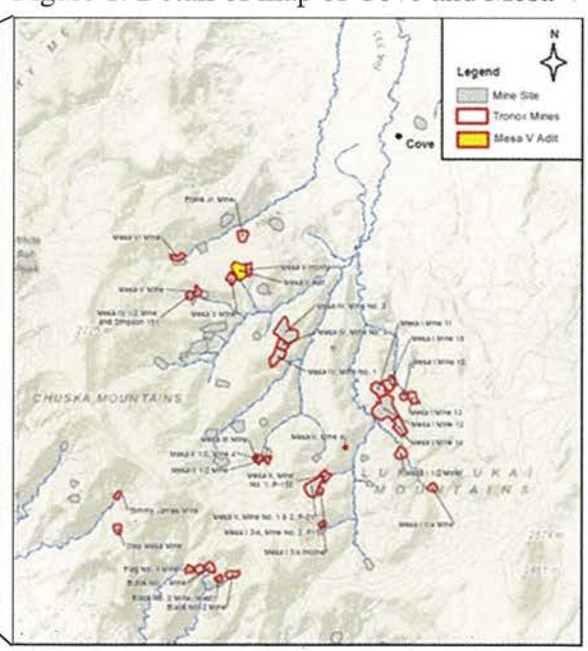


Figure 1. Detail of map of Cove and Mesa V



2 FIELD OBSERVATIONS

Upon arrival at the adit site, the team discovered that the full extent of the mineshaft consisted of a short passageway downslope to a small excavated room approximately 16 feet by 20 feet with a ceiling height of approximately 10 feet. Just inside the adit entrance, a vertical shaft extends up toward the surface of the mesa. There is a large pile of debris (rock and sand) just inside the entrance and below the vertical shaft. The shaft is estimated to extend upward approximately 100 feet. It is unknown if there are any side tunnels going out from this vertical shaft. There appeared to be timber material covering the entrance to the shaft at the top, but some light could be seen entering through or around the cover. The top entrance to this shaft was not investigated by the field team. No other indications of mining or excavations existed beyond these immediate areas. There was evidence of animal droppings within the adit and inner chamber.

3 SUMMARY OF METHODS

Since the field team found that the adit and mineshaft configuration was not as expected and described in the SAP, adjustments were made to the planned monitoring locations. All other monitoring activities for the project were performed in accordance with the Sampling Analysis Plan (SAP) for the Mesa V Mine Radon Sampling Project, dated May 24, 2017.

Consistent with the SAP, three calibrated Saphymo AlphaGUARD passive radon monitors were placed at two different locations within the adit and left to measure ^{222}Rn concentrations, statistical measurement error, temperature, pressure and humidity at 10 minute intervals for a period of 72 hours. The initial location for one sampler was to be at the entrance of the adit. Due to a large debris pile consisting of sand and rock directly inside the entrance, the field team decided to place AlphaGUARD SN 1756 approximately 30 feet inside of the adit entrance near the top of the debris pile for stability, yet allowing for adequate mixing with the outside air. The remaining two samplers, AlphaGUARD SN 1036 and 1147, were co-located inside and toward the rear of the inner chamber and were placed six feet apart and oriented in different directions for unbiased duplicate monitoring of the radon gas concentration within the chamber. With the exception of the distance to the ground surface in the vertical shaft, the adit did not extend to a distance of 100 feet as assumed in the SAP. Thus the samplers were placed in the inner most reaches of the adit.

4 MONITORING RESULTS

4.1 Adit Inner Chamber Results

AlphaGUARD SN 1147 and SN 1036 were placed inside and near the back of the adit inner chamber. Both monitors were started 06/19/2017 at 1140 Pacific Daylight Time (PDT) and turned off and retrieved 06/22/2017 at 1150 PDT. The instruments recorded data at 10 minute intervals resulting in a total of 433 sequential measurements.

Measured concentrations of ^{222}Rn over time are plotted in the chart in Figure 3. It is clear from the plot that the two samplers inside of the inner chamber did not reach full equilibrium until approximately four hours after placement. This was likely caused by the lack of air exchange or air movement within the space. The measurements remained stable once the monitors reached equilibrium. This can also be seen in the temperature, humidity and atmospheric pressure measurements described in section 4.3. The three-day average ^{222}Rn measurement data for the co-located monitors in the inner chamber is summarized in Table 1 below. The average measurement results provided in Table 1 are for the total number of measurements and for measurements with the first four hours of data removed (24 measurements). The latter value is a more accurate representation of the average radon concentrations in the inner chamber over the monitoring period. Measurement standard deviation was calculated internally for each 10-minute sampling period. The average of the standard deviation measurements is provided in Table 1. The screening level listed in Table 1 is the U.S. EPA action level for radon gas in residential scenarios. Refer to Section 5 for a discussion of measurement quality including the relative percent difference between the collocated samples.

Figure 3. Plot of inner chamber Rn-222

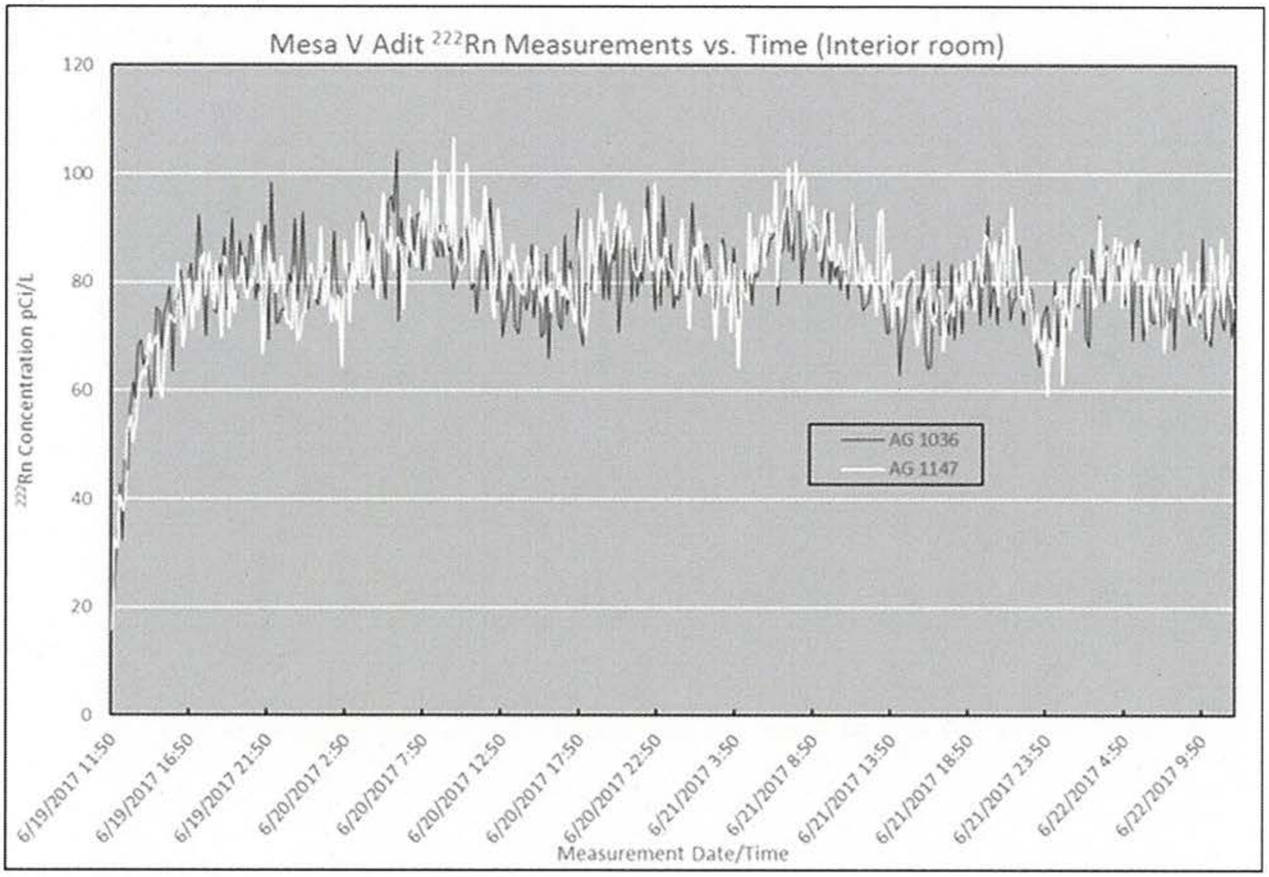


Table 1. Interior Room ^{222}Rn Measurements (co-located AlphaGUARDS)

	Average (pCi/L)	Std. Dev. (pCi/L)	Min. (pCi/L)	Max. (pCi/L)	Screening Level (pCi/L)
SN 1147 – All Data Points	80.5	9.0	30.9	106.6	4.0
SN 1147 – Minus First 4 hrs.	81.9	9.2	59.2	106.6	
SN 1036 – All Data Points	79.4	9.0	15.5	104.2	
SN 1036 – Minus First 4 hrs.	80.5	9.2	63.0	104.2	

4.2 Adit Entrance Area ^{222}Rn Results

AlphaGUARD SN 1756 was placed inside the adit entrance and started 06/19/2017 at 1130 PDT and turned off and retrieved 06/22/2017 at 1150 PDT. The instrument was set to record the average ^{222}Rn concentration, standard deviation, temperature, pressure and humidity at 10 minute intervals, resulting in a total of 434 sequential measurements. Data from this instrument showed significantly lower concentrations of ^{222}Rn but had greater variability than the two monitors in the inner chamber. Air exchange at the adit entrance was higher than in the inner chamber resulting in quicker equilibrium of the passive samplers. The data was plotted over time and clearly shows diurnal variation. See the chart in Figure 4, below. Table 2 below is a summary of the data averages for the entire 72-hour measurement period. Peak radon concentrations, typically 4 – 6 pCi/L, occurred during the late evening and overnight periods with the lowest concentrations, averaging less than 2 pCi/L, occurring during the middle of the day.

Figure 4. Plot of Adit Rn-222 concentration over time

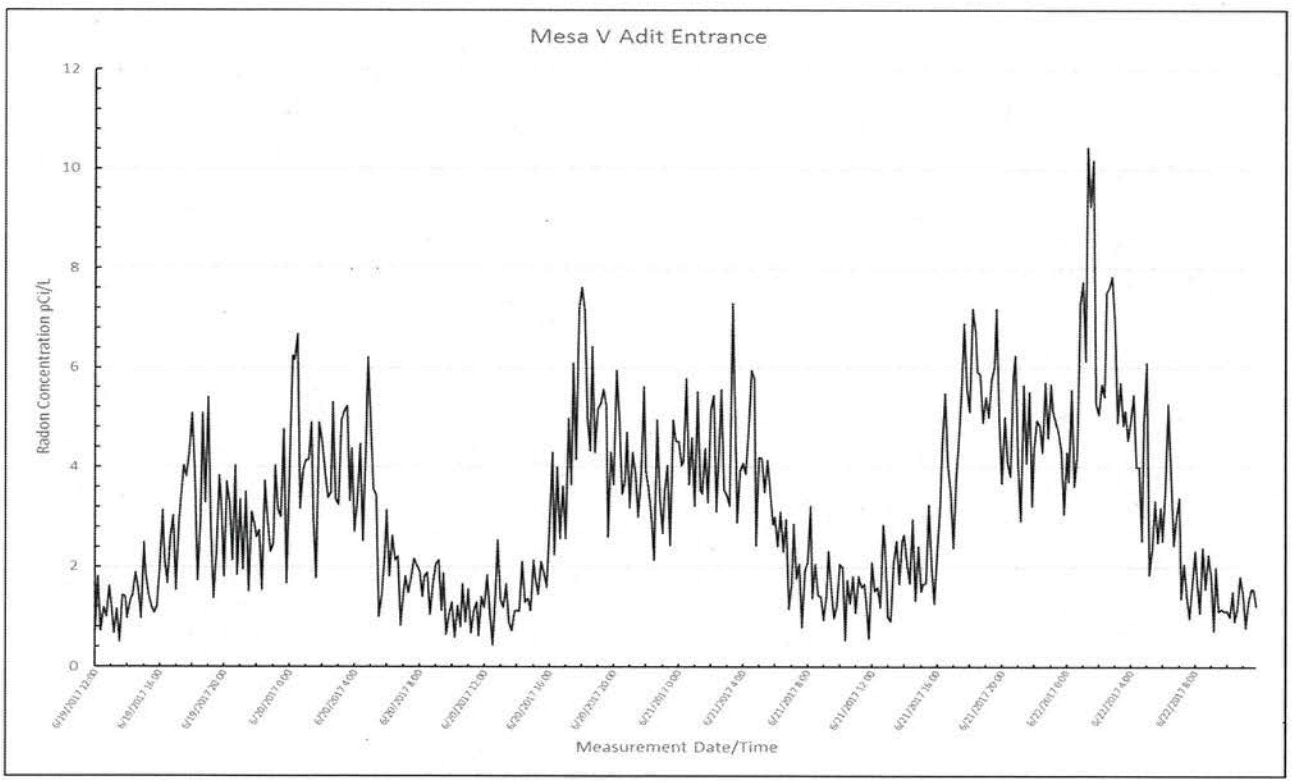


Table 2. Adit Rn-222 concentration over time

	Average (pCi/L)	Std. Dev. (pCi/L)	Min (pCi/L)	Max (pCi/L)	Screening Level (pCi/L)
All Data	3.15	0.97	0.41	10.43	4.0

Of the 433 total measurements, 430 (99.3%) were less than 7.84 pCi/L. Three peak measurements greater than 9.2 pCi/L occurred overnight at 0120 to 0140 PDT on the third sampling day, June 22, 2017.

4.3 Environmental conditions

During the radon measurement process, the AlphaGUARDs also recorded ambient temperature, pressure and relative humidity. Table 3 below is a summary of the conditions measured by the three samplers.

Table 3. Environmental conditions summary *

	Avg. Pressure inHg	Minimum Pressure inHg	Maximum Pressure inHg
AG1036 (inside room)	23.6	23.6	23.6
AG1147 (inside room)	23.6	23.6	23.6
AG1756 (Adit Entrance)	23.6	23.6	23.6
	Avg. Humidity %	Minimum Humidity %	Maximum Humidity %
AG1036 (inside room)	80.4	62.3	83.5
AG1147 (inside room)	84.0	65.0	88.0
AG1756 (Adit Entrance)	43.1	31.1	71.5
	Avg.Temperature °F	Minimum Temp. °F	Maximum Temp. °F
AG1036 (inside room)	50.6	50.0	52.3
AG1147 (inside room)	50.3	49.8	51.6
AG1756 (Adit Entrance)	63.3	56.3	71.4

*data after monitor stabilization ~ 4 hours

The monitors in the inside room took several hours to stabilize to the room temperature, but once stabilized, the room temperature did not show variation more than 1 degree during the entire 72-hour measurement period. Temperature at the adit entrance varied between 56 °F at night to 72 °F during the daytime. The humidity was stable in the inner room showing a slight increase in humidity over the three-day measurement period. The humidity at the adit entrance changed with the same diurnal variation as the temperature and radon concentration, ranging from as low as 31% during the day and over 70% during early morning hours. The atmospheric pressure was very stable over the entire sampling period in the inner room and at the adit entrance. All three monitors show no observable change in the ambient pressure. Refer to Figure 5 for a time plot of the temperature, pressure and humidity in the inner chamber. The plot in Figure 6 is for the adit entrance monitor placement.

Figure 5. Environmental measurements, inner chamber

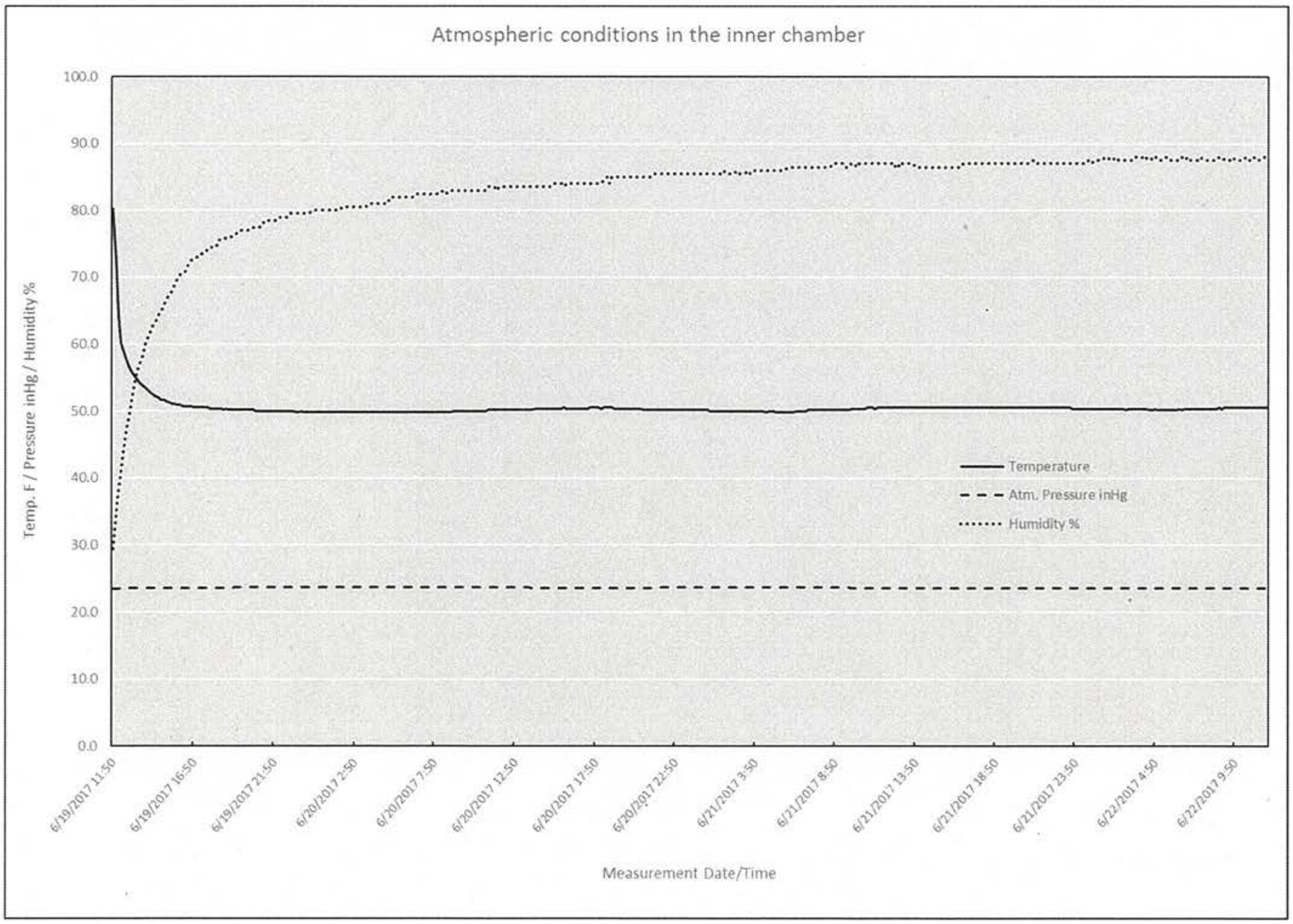
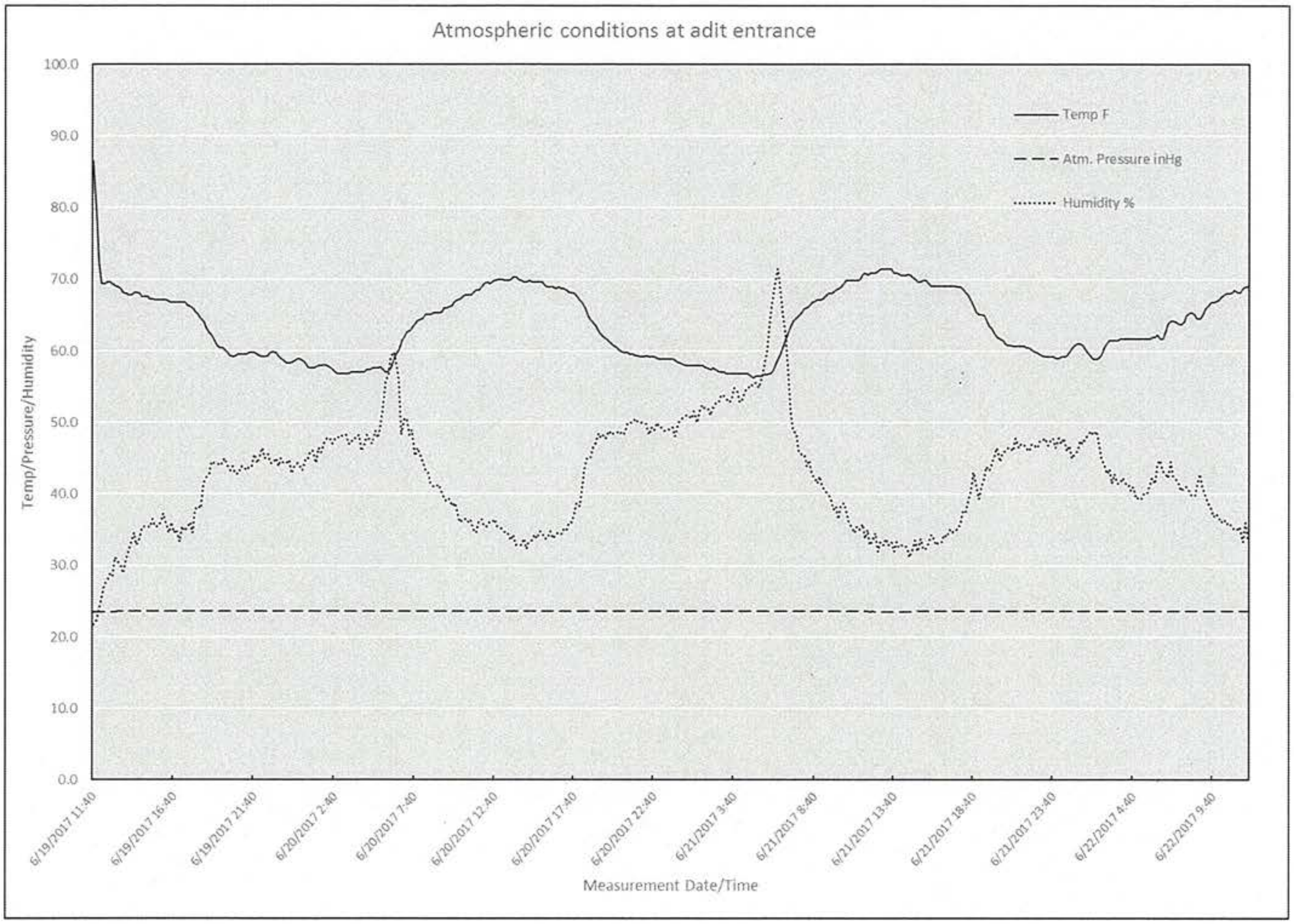


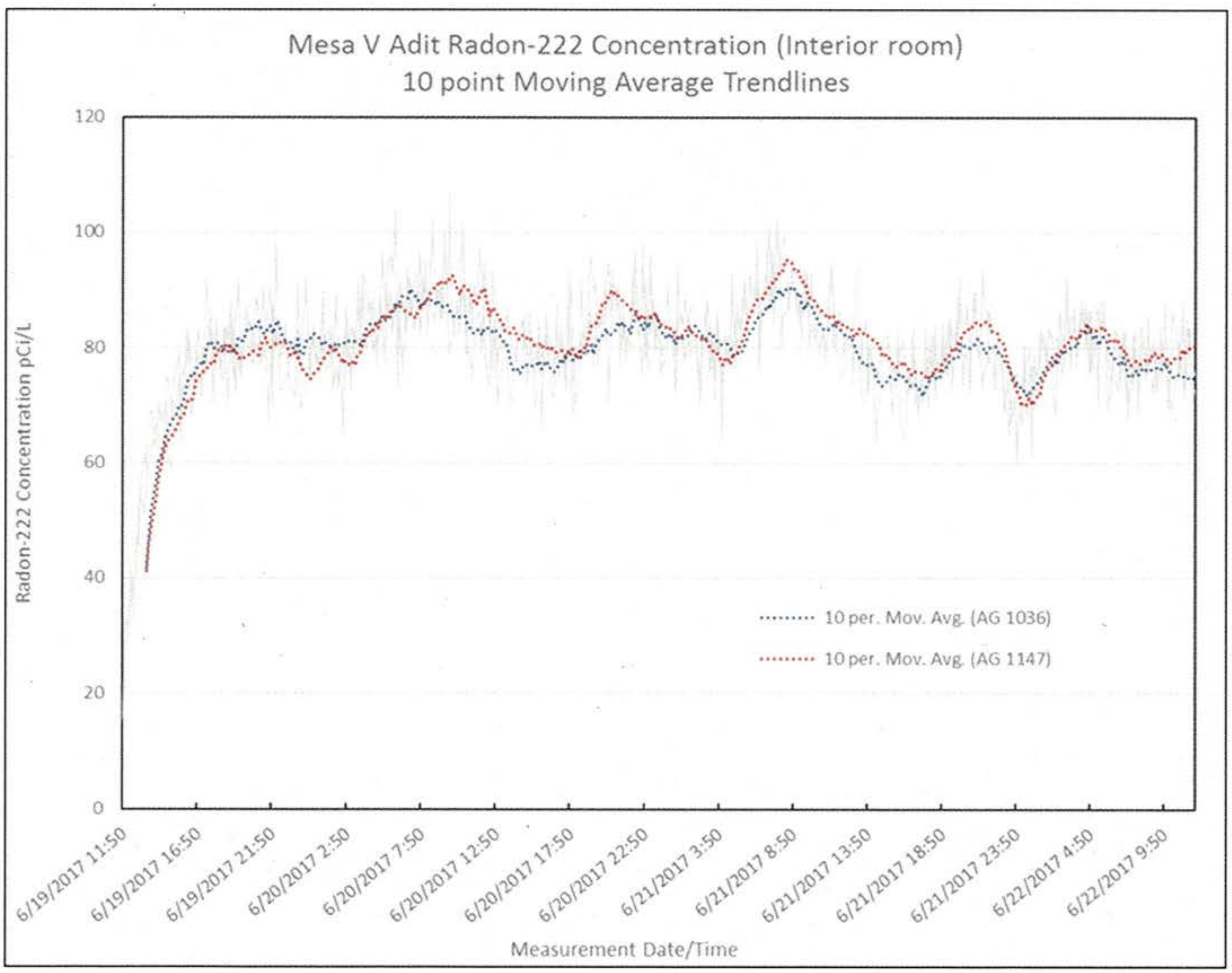
Figure 6. Environmental measurements, Adit



5 MEASUREMENT QUALITY

Data completeness was 100% with no data lost from the measurement phase or during transfer of the data for all three monitors. The Relative Percent Difference (RPD) for the measurement run was determined for each 10-minute measurement period, and for the overall averages on the co-located samplers in the inner chamber. The RPD for the overall ^{222}Rn averages was 1.40%, well within the goal of 25% stated in the SAP. The average RPD for individual ^{222}Rn measurements was 7.86%, ranging from 0.0% to 30.0%. Of the 433 measurements, only five measurements had an RPD of greater than 25% and 90% of the measured RPDs were 15% or less. The RPDs for all of the individual temperature, pressure and humidity measurements were less than 1%. A plot of the data for the two instruments inside the inner room was generated with 10-point trailing average trend lines. The plot shows excellent agreement between the two instruments over the entire 72-hour sampling period. See Figure 7, below.

Figure 7. Timeplot of radon trendlines from inner chamber



6 CONCLUSIONS

While the measured levels of ^{222}Rn are at or exceed screening levels based on residential scenarios, listed in tables 1 and 2 and the SAP, those screening levels are based on continuous or near continuous exposures that occur for many years (>25 years). Thus, when comparing them to adit ^{222}Rn levels, they would significantly overestimate risks to recreational and short-term worker receptors. The exposure receptors for the site (i.e., adit) are expected to have significantly shorter exposure time, frequency and duration due to the remoteness and accessibility of the adit. However, background exposures (e.g., at home) to radon and representativeness of the monitoring data (i.e., snapshot in time) should be considered in the evaluation and addressment of potential exposure pathways.

This event is only a snapshot in time of the radon concentrations. The diurnal variations in ^{222}Rn concentration at the adit entrance indicate that there is an increased exchange of radon during the overnight hours. The atmospheric pressure in the area was high and stable so it is unknown if the radon concentrations inside the excavation would increase with changes in weather and a drop in the atmospheric pressure.

7 REFERENCES

No references cited.

8 APPENDICES

- 8.1 Project Acceptance Form/Customer Request
- 8.2 Photographs of the Mesa V mine adit entrance and inner chamber

Appendix 8.1, Project Acceptance Form

NATIONAL CENTER FOR RADIATION FIELD OPERATIONS (NCRFO)

PROJECT ACCEPTANCE FORM

The purpose of this document is to provide NCRFO an abridgment, to ensure that all requests can be delivered while meeting quality assurance objectives. This document is not a contract. It's an internal quality control approach to ensure that NCRFO can deliver environmental radiological services, so we can meet the needs of our customer. The customer must be aware that in the event of an emergency, NCRFO resources may be redirected from your activity.

I. REQUESTER CONTACT INFORMATION

Organization: USEPA Region 9

Contact Person: Edwin "Chip" Poalinelli

Phone: 415-972-3390 Cell: 415-301-1573

Email: poalinelli.edwin@epa.gov

Signature: Edwin Poalinelli Date: 2/27/2017

II. SITE BILLING CODE (IF REQUIRED) FOR SITE SUPPORT

Certifying Officer: ______

BFY: ______

FUND/Appropriation: ______

Budget Org: ______

PRC: ______

Site Project: ______

III. PROJECT INFORMATION

Please provide a detailed site and project description including known or suspected hazards.

Site Program Type: ☑ Regional ☑ Superfund ☐ Other

Site Name: Mesa V Navajo Nation Tronox

Site Location: ______

Appendix 8.1, Project Acceptance Form, cont'd

Site History or Weblink/URL (if Available)

Proposed Project Start Date: 3/20/2017

Proposed Project End Date: 9/29/2017

Customer Proposal:

See Attachment

IV. Samples Collected by NCRFO? ☑ **YES** (Laboratory Sample Acceptance Form Needed) ☐ **NO**

V. PROPOSED APPROACH (to be completed by NCRFO personnel)

Please note that the proposed target date may change due to emergency and operational commitments.

Proposed Date: ____________________

Comments:

Appendix 8.1, Project Acceptance Form, cont'd

VI. NCRFO APPROVAL (to be completed by NCRFO personnel)

NCRFO Project Manger MARK D. SELLS

☒ Approved ☐ Disapproved Reason for Disapproval:

Comments:

Signature: Date: 3/08/2017

CRPR/CPT Center Director Jeremy O. Johnson

☒ Approved ☐ Disapproved Reason for Disapproval:

Comments:

Signature: Date: 3/8/2017

NCRFO QA Manager Emilio B Braganza

☒ Approved ☐ Disapproved Reason for Disapproval:

Comments:

Signature: Date: 3/9/2017

NCRFO Laboratory Director Edward L. Wilds Jr

☒ Approved ☐ Disapproved Reason for Disapproval:

Comments:

Signature: Date: 3/9/17

Appendix 8.1, Project Acceptance Form, cont'd

NCRFO will assist EPA Region 9 in developing and implementing a radon investigation of an adit located on the Mesa V Navajo Nation Tronox site. More specifically, NCRFO (in coordination with EPA Region 9 and Navajo Nation) will develop a work plan (including a QAPP/SAP) to sample and measure the ambient levels of radon in the adit, which will be used to evaluate/assess doses/risks to people and animals that enter or are near the adit opening. Exposure rate monitoring may also be performed to more fully characterize the adit and immediate vicinity during the radon investigation. The work plan (including QAPP/SAP) will include, but is not limited to the development of a conceptual site model, data quality objectives, and screening levels (to assess risks/doses).

During the development of the work plan, NCRFO staff will visit the site at least once for the purposes of gaining more complete understanding of site conditions and field work limitations. In addition, NCRFO and EPA Region 9 staff will hold regular meetings (at least monthly) to discuss work plan elements and objectives and other project related issues (analytical needs, Health and Safety).

EPA Region 9 also proposes that a small NCRFO field team implement the work plan, with RPM oversight. Upon completion of the investigation and analysis of samples, NCRFO will develop and provide a report to EPA Region 9 on the findings of the investigation. Region 9 will provide the overall approval of all work plans/QAPPs/investigation reports.

EPA Region 9 will make arrangements with a contract lab to perform sample analysis and supplying the data to NCRFO.

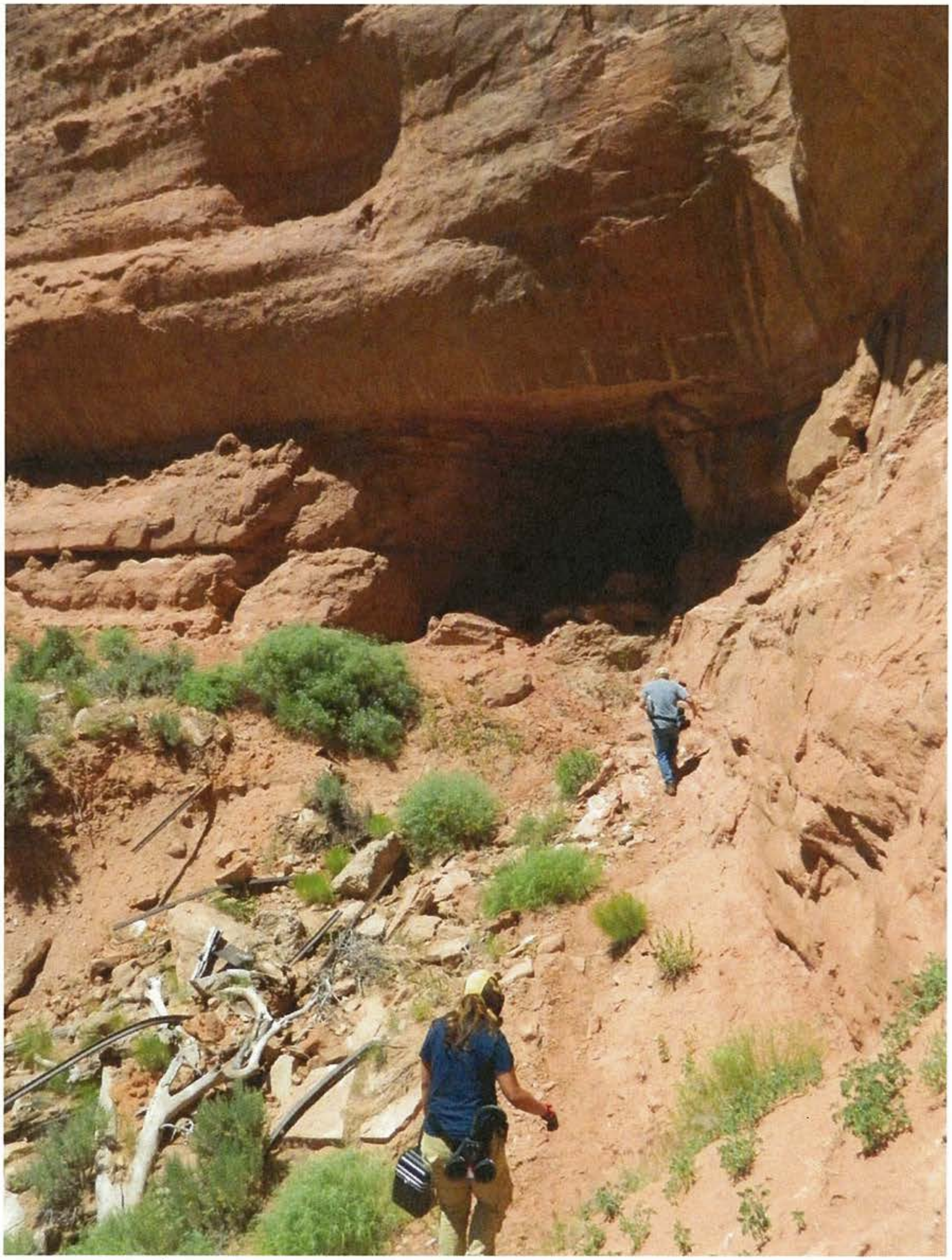
EPA Region 9 will also provide NCRFO all site coding/billing information along with all relevant site background information and health and safety plans

Appendix 8.2, Photos of Mesa V Adit

Mesa V adit in the distance (approach on foot)

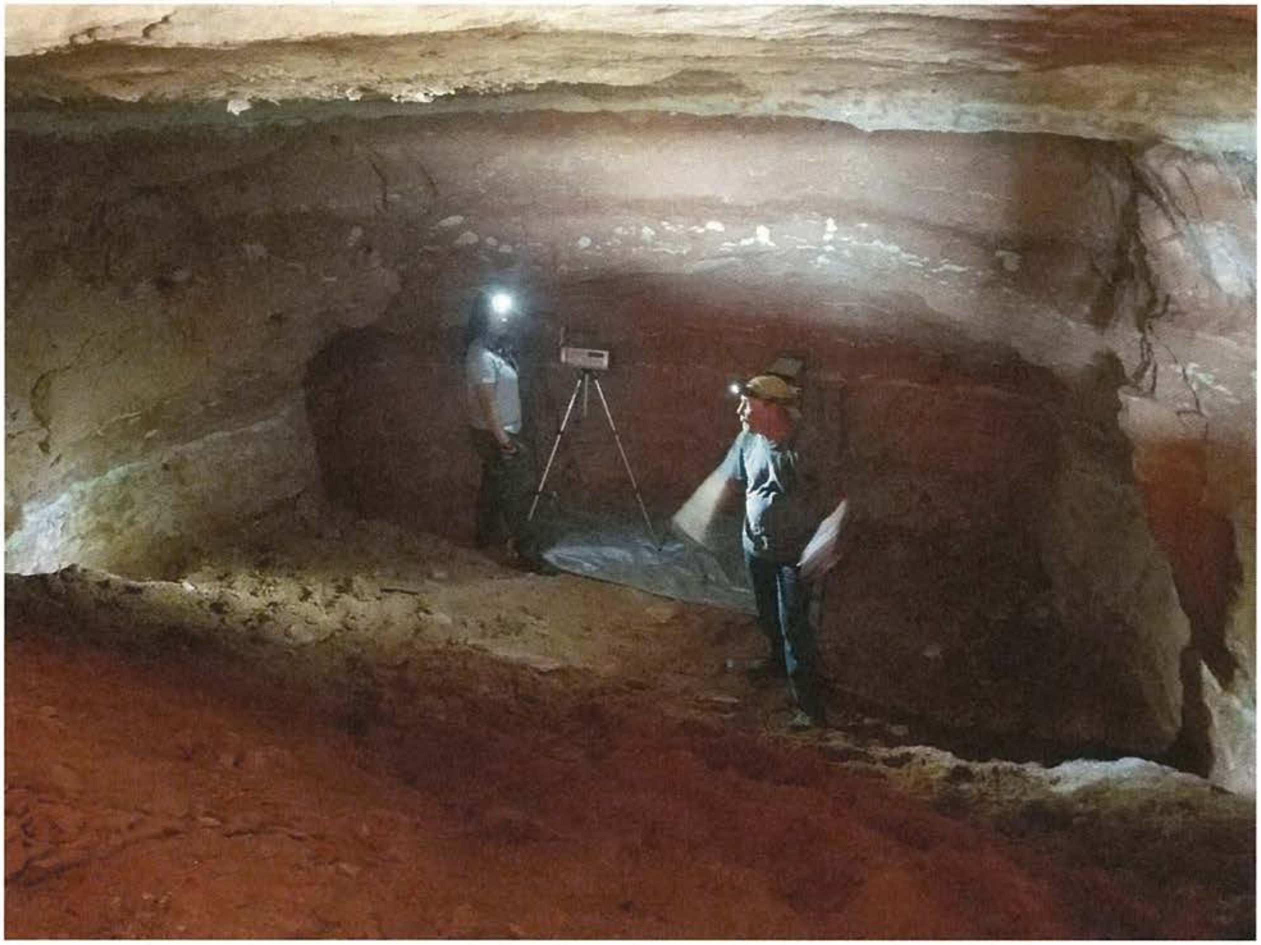
Appendix 8.2, Photos of Mesa V Adit, cont'd

Team arrival at the Mesa V adit



Appendix 8.2, Photos of Mesa V Adit, cont'd

Monitoring in the Mesa V inner chamber



ATTACHMENT V
ATSDR ToxFAQ (Radon, Uranium, and Radium)

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

RADIUM
CAS # 7440-14-4

Agency for Toxic Substances and Disease Registry ToxFAQs July 1999

This fact sheet answers the most frequently asked health questions (FAQs) about radium. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It's important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Radium is a radioactive substance formed from the breakdown of uranium and thorium. Exposure to high levels results in an increased risk of bone, liver, and breast cancer. This chemical has been found in at least 18 of the 1,177 National Priorities List sites identified by the Environmental Protection Agency (EPA).

What is radium?

(Pronounced rā′dē-əm)

Radium is a naturally occurring silvery-white radioactive metal that can exist in several forms called isotopes. Radium is formed when uranium and thorium break down in the environment. Uranium and thorium are found in small amounts in most rocks and soil. Two of the main radium isotopes found in the environment are radium-226 and radium-228.

Radium undergoes radioactive decay. It divides into two parts—one part is called radiation and the other part is called a daughter. The daughter, like radium, is not stable, and it also divides into radiation and another daughter. The dividing of daughters continues until a stable, nonradioactive daughter is formed. During the decay process, alpha, beta, and gamma radiation are released. Alpha particles can travel only a short distance and cannot travel through your skin. Beta particles can penetrate through your skin, but they cannot go all the way through your body. Gamma radiation can go all the way through your body.

Radium has been used as a radiation source for treating cancer, in radiography of metals, and combined with other metals as a neutron source for research and radiation instrument calibration. Until the 1960s, radium was a component of the luminous paints used for watch and clock dials, intrument panels in airplanes, military instruments, and compasses.

What happens to radium when it enters the environment?

- Radium is constantly being produced by the radioactive decay of uranium and thorium.
- Radium is present at very low levels in rocks and soil and may strongly attach to those materials.
- Radium may also be found in air.
- High concentrations are found in water in some areas of the country.
- Uranium mining results in higher levels of radium in water near uranium mines.
- Radium in the soil may be absorbed by plants.
- It may concentrate in fish and other aquatic organisms.

How might I be exposed to radium?

- Everyone is exposed to low levels of radium in the air, water, and food.

- Higher levels may be found in the air near industries that burn coal or other fuels.
- It may be found at higher levels in drinking water from wells.
- Miners, particularly miners of uranium and hard rock, are exposed to higher levels of radium.
- It may also be found at radioactive waste disposal sites.

How can radium affect my health?

Radium has been shown to cause effects on the blood (anemia) and eyes (cataracts). It also has been shown to affect the teeth, causing an increase in broken teeth and cavities. Patients who were injected with radium in Germany, from 1946 to 1950, for the treatment of certain diseases including tuberculosis were significantly shorter as adults than people who were not treated.

How likely is radium to cause cancer?

Exposure to high levels of radium results in an increased incidence of bone, liver, and breast cancer. The EPA and the National Academy of Sciences, Committee on Biological Effects of Ionizing Radiation, has stated that radium is a known human carcinogen.

Is there a medical test to show whether I've been exposed to radium?

Urine tests can determine if you have been exposed to radium. Another test measures the amount of radon (a breakdown product of radium) in exhaled air. Both types of tests require special equipment and cannot be done in a doctor's office. These tests cannot tell how much radium you were exposed to, nor can they be used to predict whether you will develop harmful health effects.

Has the federal government made recommendations to protect human health?

The EPA has set a drinking water limit of 5 picocuries per liter (5 pCi/L) for radium-226 and radium-228 (combined).

The EPA has set a soil concentration limit for radium-226 in uranium and thorium mill tailings of 5 picocuries per gram (5 pCi/g) in the first 15 centimeters of soil and 15 pCi/g in deeper soil.

The federal recommendations have been updated as of July 1999.

Glossary

Anemia: A decreased ability of the blood to transport oxygen.

Carcinogen: A substance that can cause cancer.

CAS: Chemical Abstracts Service.

National Priorities List: A list of the nation's worst hazardous waste sites.

Picocurie (pCi): A unit used to measure the quantity of radioactive material.

rem: A unit used to measure radiation dose.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological profile for radium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Radon - ToxFAQs™

CAS # 10043-92-2 and 14859-67-7

This fact sheet answers the most frequently asked health questions (FAQs) about radon. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Radon is an odorless, colorless, tasteless, naturally-occurring radioactive gas formed from the breakdown of uranium and thorium. Exposure to high levels results in an increased risk of lung cancer.

What is radon?

Radon is a naturally occurring, radioactive, noble gas that is odorless, colorless, and tasteless. It is formed as part of three radioactive decay chains that begin with uranium or thorium. These elements are found in small amounts in most rock, soil, and water. Each atom of uranium or thorium decays or transforms about a dozen times, each time expelling radiation and forming a different element with different radioactive properties. Radium and then radon are formed midway through these decay chains.

Since radon is a noble gas, it releases from any chemical bonds that attach it, and it may travel far enough to reach groundwater or the air.

Radon progeny is the term given to those radioactive atoms with short half-lives into which radon quickly decays. Air, soil, and water contain many atoms that are at various points in these decay chains. A sample of any one is expected to contain a mixture of these radioactive elements or radionuclides, including radon and radon progeny.

What happens to radon when it enters the environment?

- Radon gas released from rocks and soil can move to air, groundwater, and surface water.
- Radon-222 has a radioactive half-life of about 4 days; this means that one-half of a given amount of radon will decay to radon progeny every 4 days.
- Radon progeny are solid particles that can be trapped inside the earth or, if in the air when radon decays, can attach to dust and other particles and move with the air. Radon progeny that are attached to dust can be removed by air filters.

How might I be exposed to radon and radon progeny?

- Radon is normally found at very low levels in outdoor air.
- Radon progeny are often attached to dust; you are exposed to them primarily by breathing them in.
- Radon and radon progeny are normally found at higher levels in indoor air in homes, schools, and office buildings.
- Concrete construction materials or cracks in the basement or foundation of a home may allow higher levels of radon and radon progeny inside the home.
- Elevated levels of radon and radon progeny can be found in areas with elevated levels of uranium or thorium. This can include most any mining or milling operation involving metals or phosphates.
- Radon and radon progeny are normally found in surface and groundwater and are expected to be in drinking water from these sources. They are also found in drinking water from wells that contain radon. Radon in water can become airborne especially when the water is used for cooking or showering.

How can radon and radon progeny affect my health?

When radon or radon progeny undergo radioactive decay, some of the decays expel high-energy alpha particles, which are the main source of health concerns. The main isotope of health concern is radon-222 (^{222}Rn).

Many scientists believe that the alpha radiation dose from long-term exposure to elevated levels of radon progeny in air increases your chance of getting lung cancer. Cigarette smoking greatly increases your chance of developing lung cancer if you are exposed to radon and radon progeny at the same levels as people who do not smoke.

How likely are radon and radon progeny to cause cancer?

The Department of Health and Human Services (DHHS), International Agency for Research on Cancer (IARC), and the Environmental Protection Agency (EPA) consider radon to be a human carcinogen. The greater your exposure to radon, especially if you smoke cigarettes, the greater your chance of developing lung cancer.

How can radon and radon progeny affect children?

Smaller lungs and faster breathing rates may result in higher radiation doses to the lungs of children relative to adults. However, limited information from children employed as miners in China do not provide evidence of increased susceptibility to the effects of exposure to radon.

How can families reduce the risk of exposure to radon and radon progeny?

Indoor radon and radon progeny levels can be reduced by methods that include sealing the pathways through which radon can enter a building and installing a ventilation system that routes air from underneath the building (either under the slab or in the crawl space) to outdoor air. For more information, contact your state radon office, a professional radon testing and mitigation firm, the National Environmental Health Association's National Radon Proficiency Program, or the National Radon Safety Board.

Is there a medical test to determine whether I've been exposed to radon and radon progeny?

Radon in human tissues is not detectable by routine medical testing. Some radon progeny can be detected in urine and in lung and bone tissue. These tests cannot tell how much radon you were exposed to, nor can they be used to predict whether you will develop harmful health effects. Radon exposure is estimated by measuring radon levels in the air.

Has the federal government made recommendations to protect human health?

The EPA recommends fixing your home if measured indoor levels of radon are 4 or more picocuries per liter of air (4 pCi/L). The EPA also notes that radon levels less than 4 pCi/L still pose a health risk and can be reduced in many cases. If indoor radon levels need to be reduced, the EPA recommends using a certified radon mitigation specialist to ensure that appropriate methods are used to reduce radon levels.

The Mine Safety and Health Administration (MSHA) has adopted an exposure limit of 4 Working Level Months (WLM) per year for people who work in mines (WLMs basically combine the concentration of radon progeny in mine air with length of exposure inside the mine).

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2012. Toxicological Profile for Radon. Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.

Phone: 1-800-232-4636 FAX: 770-488-4178.

ToxFAQs™ Internet address via WWW is http://www.atsdr.cdc.gov/toxfaqs/index.asp.

ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Natural & Depleted Uranium - ToxFAQs™

CAS # 7440-61-1

This fact sheet answers the most frequently asked health questions (FAQs) about natural and depleted uranium. For more information, call the CDC Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Natural uranium is a naturally occurring chemical substance that is mildly radioactive. Depleted uranium is an adjusted mixture of natural uranium isotopes that is less radioactive. Everyone is exposed to low amounts of uranium through food, water, and air. Exposure to high levels of natural or depleted uranium can cause kidney disease. Uranium has been found in at least 67 of 1,699 National Priorities List (NPL) sites identified by the Environmental Protection Agency (EPA).

What is uranium?

Uranium is a naturally occurring radioactive element. It is naturally present in nearly all rocks, soils, and air; can be redistributed in the environment through wind and water erosion; and more can be released into the environment through volcanic eruptions. Natural uranium is a mixture of three isotopes: ^{234}U,235U, and ^{238}U. The most common isotope is ^{238}U; it makes up over 99% of natural uranium. All three isotopes behave the same chemically, but they have different radioactive properties. The half-lives of uranium isotopes (the amount of time needed for half of the isotope to give off its radiation and change into a different element) is very long. The least radioactive isotope is ^{238}U with a half life of 4.5 billion years. Depleted uranium is a mixture of the same three uranium isotopes except that it has very little ^{234}U and ^{235}U. It is less radioactive than natural uranium. Enriched uranium is another mixture of isotopes that has more ^{234}U and ^{235}U than natural uranium. Enriched uranium is more radioactive than natural uranium.

Uranium is almost as hard as steel and much denser than lead. Natural uranium is used to make enriched uranium; depleted uranium is the leftover product. Enriched uranium is used to make fuel for nuclear power plants. Depleted uranium is used as a counterbalance on helicopters rotors and airplane control surfaces, as a shield to protect against ionizing radiation, as a component of munitions to help them penetrate enemy armored vehicles, and as armor in some parts of military vehicles.

What happens to uranium when it enters the environment?

- Natural and depleted uranium that exist in the dust in the air settle onto water, land, and plants. Uranium deposited on land can be reincorporated into soil, washed into surface water, or stick to plant roots. Uranium in air, surface water, or groundwater can be transported large distances.

How might I be exposed to uranium?

- Food and drinking water are the primary sources of intake for the general public. Very low levels of uranium are found in the air.
- Root crops such as potatoes, parsnips, turnips, and sweet potatoes contribute the highest amounts of uranium to the diet. Because uranium in soil can stick to these vegetables, the concentrations in these foods are directly related to the concentrations of uranium in the soil where the foods are grown.
- In most areas of the United States, low levels of uranium are found in the drinking water. Higher levels may be found in areas with elevated levels of naturally occurring uranium in rocks and soil.
- People may be exposed to higher levels of uranium if they live near uranium mining, processing, and manufacturing facilities. People may also be exposed if they live near areas where depleted uranium weapons are used.

How can uranium enter and leave my body?

Most of the uranium you breathe or ingest is not absorbed and leaves the body in the feces. Absorbed uranium is deposited throughout the body. The highest levels are found in the bones, liver, and kidneys; 66% of the uranium in the body is found in your bones. It can remain in the bones for a long time; the half-life of uranium in bones is 70–200 days. Most of the uranium that is not in bones leaves the body in the urine in 1–2 weeks.

How can uranium affect my health?

Natural uranium and depleted uranium have the identical chemical effect on your body. Kidney damage has been seen in humans and animals after inhaling or ingesting uranium compounds. However, kidney damage has not been consistently found in soldiers who have had uranium metal fragments in their bodies for several years. Ingesting water-soluble uranium compounds will result in kidney effects at lower doses than following exposure to insoluble uranium compounds.

Studies in animals have shown that inhalation exposure to insoluble uranium compounds can result in lung damage. In male rats and mice, exposure to uranium has been shown to decrease fertility. Uranium compounds on the skin caused skin irritation and mild skin damage in animals.

Health effects of natural and depleted uranium are due to chemical effects and not to radiation.

How likely is uranium to cause cancer?

Neither the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC) nor the EPA have classified natural uranium or depleted uranium with respect to carcinogenicity.

How can uranium affect children?

The health effects seen in children from exposure to toxic levels of uranium are expected to be similar to the effects seen in adults.

Exposure of animals to high levels of uranium during pregnancy, which caused toxicity in the mothers, has induced early deaths and birth defects in the young. It is not clear if this can happen in the absence of effects on the mother. We do not know whether uranium can cause birth defects in people. There are some studies that suggest that exposure to depleted uranium increased the frequency of birth defects, but the studies are deficient to allow valid conclusions.

How can families reduce the risk of exposure to uranium?

- Avoid eating root vegetables grown in soils with high levels of uranium. Consider washing fruits and vegetables grown in that soil and discard the outside portion of root vegetables.
- Consider having your water tested if you suspect that your drinking water might have elevated levels of uranium; if elevated levels are found, consider using bottled water.

Is there a medical test to determine whether I've been exposed to uranium?

Natural uranium is in your normal diet, so there will always be some level of uranium in all parts of your body. If depleted uranium is present, it adds to the total uranium level. Uranium can be measured in blood, urine, hair, and body tissues. Most tests are for total uranium; however, expensive tests are available to estimate the amounts of both natural and depleted uranium that are present.

Has the federal government made recommendations to protect human health?

The government has made recommendations for uranium which apply to natural and depleted uranium combined.

The EPA established a maximum drinking water contaminant level of 0.03 mg/L.

The Occupational Safety and Health Administration (OSHA) has limited workers' exposure in air to an average of 0.05 mg U/m^3 for soluble uranium and 0.25 mg U/m^3 for insoluble uranium over an 8-hour workday.

The National Institute for Occupational Safety and Health (NIOSH) recommends workers exposure be limited to 0.05 mg U/m^3 of air for soluble uranium and 0.2 mg U/m^3 for insoluble uranium averaged over a 10-hour workday and recommends that exposure to soluble uranium not exceed 0.6 mg U/m^3 for more than 15 minutes.

The Nuclear Regulatory Commission (NRC) has established air concentration limits for uranium and its individual isotopes that apply to occupational exposure and releases from facilities.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2013. Toxicological Profile for Uranium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information?

For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Human Health Sciences, 1600 Clifton Road NE, Mailstop F-57, Atlanta, GA 30329-4027.

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